(12) UK Patent Application (19) GB (11) 2 345 866 (13) A

(43) Date of A Publication 26.07.2000

(21) Application No 9928626.2

(22) Date of Filing 03.12.1999

(30) Priority Data
(31) 9826463 (32) 03.12.1998 (33) GB

(71) Applicant(s)
Rover Group Limited
(Incorporated in the United Kingdom)
International Headquarters,
Warwick Technology Park, WARWICK, CV34 6RG,
United Kingdom

(72) Inventor(s)
Adam James Smith

(74) Agent and/or Address for Service
Robert Michael Farrow
Rover Group Limited, Gaydon Test Centre, Banbury
Road, LIGHTHORNE, Warwick, CV35 0RG,
United Kingdom

(51) INT CL[7]
F01N 3/08 , B01D 53/22 53/94

(52) UK CL (Edition R)
B1W WAX W10C W10D W16X W2P W6A W6W W8B

(56) Documents Cited
DE 004331508 C DE 004117829 A1 JP 060319949 A
JP 060319948 A US 5649517 A

(58) Field of Search
UK CL (Edition R) B1W WAX
INT CL[7] B01D 53/22 53/94 , F01N 3/08 3/10 3/24 3/28
7/00
On-line: WPI, EPODOC, PAJ

(54) Abstract Title
Separating oxygen from exhaust stream

(57) In an internal combustion engine installation, an exhaust arrangement (3) includes an exhaust gas s paration membrane (22) which separates the exhaust gas from the engine (17) into an oxygen-enriched stream (23) and an oxygen depleted stream (24). The oxygen depleted stream (23) is presented to a converter (25) whereby oxides of nitrogen are diminished whilst the oxygen-enriched stream (24) may be used to supplement oxygen enriched air supplied to the engine from an inlet air separation membrane (8). A plasma generator (19) uses the nitrogen enriched air from the inlet air separation membrane to create free radicals of nitrogen to react with oxygen-rich exhaust from the engine.

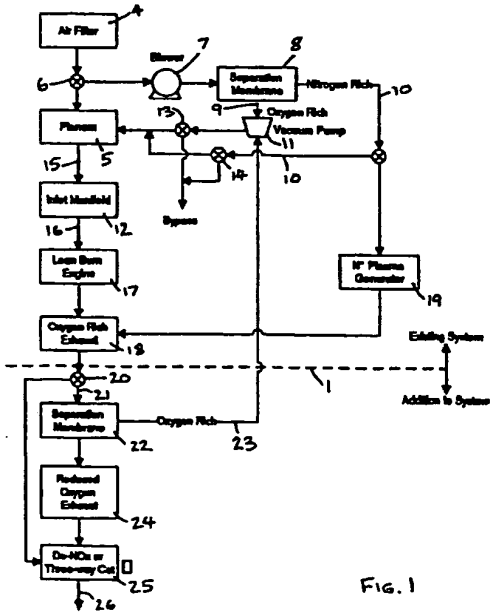

FIG. 1

GB 2 345 866 A

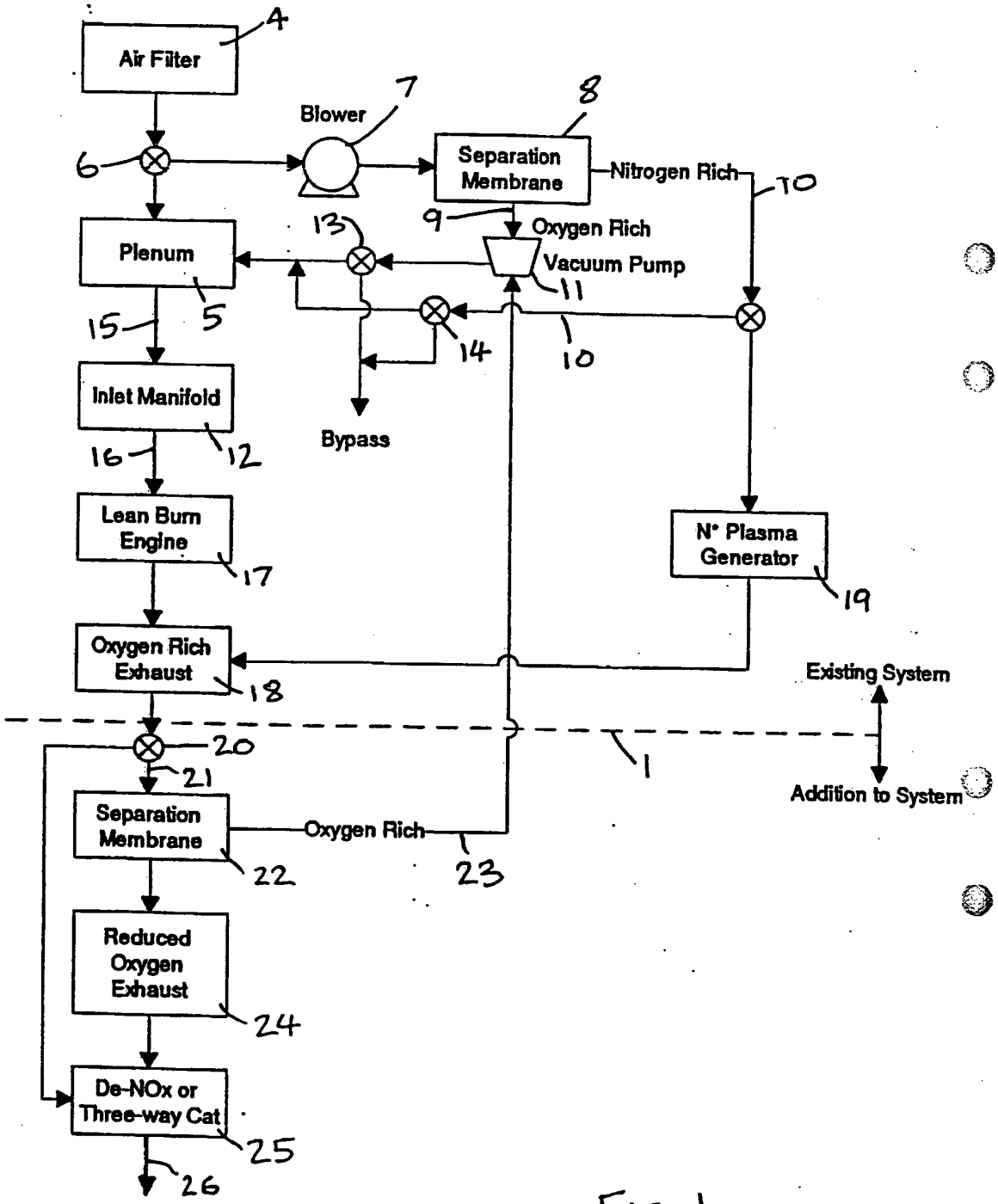
Air Filter
4
Blower
7
8
Separation Membrane
Nitrogen Rich
10
9
Oxygen Rich
Vacuum Pump
11
13
Plenum
5
15
14
10
Inlet Manifold
12
16
Bypass
Lean Burn Engine
17
N* Plasma Generator
19
Oxygen Rich Exhaust
18
Existing System
1
Addition to System
20
21
Separation Membrane
22
Oxygen Rich
23
Reduced Oxygen Exhaust
24
De-NOx or Three-way Cat
25
26

FIG. 1

AN ENGINE INLET AND EXHAUST ARRANGEMENT

The present invention relates to an inlet and exhaust arrangement for an internal combustion engine and more particularly to an exhaust arrangement used with conversion means for oxides of nitrogen in order to provide more environmentally acceptable exhaust emissions.

There is an ongoing challenge to motor vehicle manufacturers to produce vehicles with increasing environmentally acceptable exhaust emissions. Over recent years, significant advances have been made to engine management systems and inlet and exhaust arrangements in order to limit and clean exhaust gases prior to emission from the vehicle. Unfortunately, a particularly noxious element of exhaust gas is the oxides of nitrogen component.

In order to remove oxides of nitrogen or 'de-nox' exhaust gas, it is preferable to remove or diminish the oxygen content within the exhaust gas in order to produce a more reducing composition. A reduced oxygen component within the exhaust gas allows, through chemical reaction, removal of oxides of nitrogen. Conversely, oxygen in the exhaust gas inhibits the conversion of oxides of nitrogen by preferential chemical reaction, etc.

It has been proposed to use separation membranes to provide oxygen enrichment for the air input to the engine. An example of the proposed use of separation membranes is in the paper entitled "Variable Air Composition with Polymer Membrane - A New Low Emissions Tool" (Society of Automotive Engineers 980178, page 43-46). The purpose of oxygen enrichment is to promote stochiometric air/fuel proportioning within the combustion chamber of the engine or otherwise in order to promote the most advantageous exhaust gas emissions and ngine performance. Typically, lambda sensors are used to analyse the

exhaust gas in order to tune the air/fuel ratio to achieve desired results for particular environmental conditions, engine load and fuel economy.

It is an object of the present invention to provide an engine inlet and exhaust arrangement which can further improve environmental acceptability by diminution of oxides of nitrogen in the exhaust gases from the engine.

In accordance with one aspect of the present invention there is provided an inlet and exhaust arrangement for an internal combustion engin , the arrangement comprising a conduit to present exhaust gas from the engine to an exhaust gas separation membrane whereby the exhaust gas can be divided into a relatively oxygen-enriched stream and a relatively oxygen depleted stream, the oxygen depleted stream being coupled to a converter wherein oxides of nitrog n can be diminished.

The conduit may include a bypass whereby the exhaust gas can be directly coupled to the converter means.

Preferably, free radicals of nitrogen are injected into the exhaust gas to promote reduction of oxides of nitrogen from the exhaust gas, in which case the free radicals of nitrogen may be injected into the exhaust gas upstream of the exhaust gas separation membrane. Such nitrogen-free radicals may be provided by a plasma generator which utilises a nitrogen-enriched air stream from an air inlet separator membrane used in the air inlet of the engine.

Preferably, the converter is a three-way catalytic converter.

The relatively oxygen-enriched stream from the exhaust gas separation membrane may be coupled to means for altering the composition of inlet air presented to the engine.

The invention also provides, in accordance with another aspect thereof, an internal combustion engine installation including an inlet and exhaust arrangement in accordance with said one aspect wherein the installation includes control means whereby the composition of inlet air presented to the engine can be altered by mixing the relatively oxygen-enriched stream with existing air streams presented to the engine.

An embodiment of the present invention will now be described by way of example and with reference to the accompanying drawing, in which:

Fig.1 is a flow diagram illustrating operation of an internal combustion engine inlet and exhaust arrangement according to the invention.

In the flow diagram shown in Fig.1, the arrangement represented by the components above the broken line 1 is generally as previously proposed whereas the arrangement represented by the components below the broken line 1 is generally as proposed in accordance with the present invention.

Air is drawn through an air filter 4 towards a plenum 5 via a valve 6 which directs a proportion of the air flow through a blower 7 towards an air inlet separation membrane 8 whilst the remainder of the air flow enters the plenum 5. The air inlet separation membrane 8 provides a relatively oxygen-enriched air flow 9 and a relatively oxygen-depleted (and therefore relatively nitrogen-rich) air flow 10. A vacuum pump 11 is arranged to draw the oxygen enriched air flow or stream 9 through the inlet separation membrane 8 to leave the oxygen depleted (nitrogen-rich) stream 10.

The oxygen enriched stream 9 allows, through appropriate engine management control, variation of the air/fuel ratio conditions within the engine. By adjusting the proportions of air fed directly through the plenum 5 with the

oxygen enriched flow 9, the composition of the air presented to an inlet manifold 12 for combustion with fuel in the engine can be varied. Furthermore, through a combination of valves 13, 14, the oxygen-enriched air flow 9 can itself be adjusted through further proportional recombination with the nitrogen-enriched stream 10. The valve 6, blower 7, inlet separation membrane 8 and pump 11 allow adjustment of the oxygen constituent within the air presented to the inlet manifold 12. The plenum 5 allows mixing of the direct air flow through the valve 6 from the air filter 4 with the oxygen-enriched air flow 9. It will be understood that the air flow into the plenum 5 for combination with the direct air flow through the valve 6 could be relatively nitrogen enriched and therefore oxygen depleted if necessary in order to achieve an appropriate air composition for the inlet manifold 12. The appropriately proportioned inlet air 15 is presented to an engine 17 which may be a spark ignition or compression ignition type.

With regard to environmental emissions, the combustion in the engine 17 should be as near complete as possible. A stochiometric combination of air and fuel should theoretically ensure conversion during combustion. However, it will be understood that within the narrow time span and inherently turbulent, non-linear condition of any combustion chamber, complete combustion is difficult if not impossible to achieve consistently, if at all. Thus, the exhaust gas 18 from the engine 17 will normally incorporate various combustion products which are environmentally undesirable. In the case of compression ignition engines and lean-burn spark-ignition engines (which can have many advantages regarding complete combustion), there is also a tendency for oxides of nitrogen to be present in the exhaust.

It is known that exhaust gases from combustion engines can be processed according to the Zeldovich reactions listed below. By combining nitrogen atoms

with NO, O_2 and OH reagents, some of the oxides of nitrogen can be removed. The Zeldovich reactions are:

$$O + N_2 \rightarrow NO + N$$
$$N + NO \rightarrow N_2 + O$$

$$N + O_2 \rightarrow NO + O$$
$$O + NO \rightarrow O_2 + N$$

$$N + OH \rightarrow NO + H$$
$$H + NO \rightarrow OH + N$$

Due to preferential oxidation of the free-radicals of nitrogen (N), it is necessary to reduce the oxygen (O_2) constituent to promote the Zeldovich reactions by altering the balance of available reagents. Clearly, it may be uneconomic and impractical in terms of the necessary apparatus and time scale to completely remove the oxygen constituent from the notionally oxygen-rich exhaust 18. However, where required, such complete removal of oxygen may be substantially achieved or at least attempted. It has been proposed to provide a nitrogen free-radical plasma generator 19 to present nitrogen free-radicals to the exhaust 18 in order to promote the Zeldovich reactions and, through appropriate engine management, the oxygen content within the exhaust 18 by adjustment of the inlet air oxygen content, dependent upon operational conditions, workload and environmental objectives. In any event, maximisation of the Zeldovich reactions has not been achieved through further oxygen depletion in the exhaust gas 18.

In accordance with the present invention an exhaust arrangement 3 is provided in which the benefits of the Zeldovich reaction described above along with the catalytic effects of known exhaust gas converters are utilised in order to reduce

detrimental noxious exhaust emissions. Exhaust gas 18 is passed through a valv 20 such that at least a proportion 21 of the exhaust gas is presented to an exhaust gas separation membrane 22 in order to split the exhaust gas into a relatively oxygen-enriched stream 23 and a relatively oxygen depleted stream 24. The valve 20 proportions the exhaust gas flow between the membrane 22 and a direct bypass route to a converter 25. It will be appreciated that generally it is inconvenient or unacceptably limiting upon engine performance 17 to require that all exhaust gas is passed through the membrane 22 in order to maximise oxygen depletion. However, full exhaust gas passage through the membrane 22 may be conducted where required The valve 20 and the exhaust gas separation membrane 22 are downstream of the nitrogen free-radicals from the plasma generator 19, although it may be convenient to inject this just upstream of the converter 25.

The converter 25 may operate principally upon the Zeldovich reaction in which nitrogen-free radicals are combined with oxides of nitrogen in order to produce gaseous nitrogen (N_2) and an oxygen radical which readily combines with other oxygen radicals to produce gaseous oxygen (O_2). However, more conventionally a motor vehicle including an engine 17 will already incorporate a catalytic converter for conversion of oxides of nitrogen and other noxious exhaust gas component such as carbonmonoxide, etc. Thus, the converter 25 will typically itself include an appropriate catalyst to precipitate elimination of oxides of nitrogen from the exhaust gas emission 26. The reduction in the oxygen content by the exhaust arrangement 3 of the present invention further promotes elimination of such oxides of nitrogen through reduction of the stifling effects of preferred oxidation in the converter 25.

The oxygen-enriched stream 23 can be coupled to the vacuum pump 11 in order to promote a pressure differential across the exhaust separation membrane 22 and also augment the oxygen-enriched air stream 9.

The operation of catalytic conversion along with other emission control mechanisms is described in the text book entitled "The Motor Vehicle" by Newton, Steeds and Garret, published by Butterworth Heinemann (Edition 12), Part 1, Chapter 12, pages 424-457 and in particular with regard to three-way catalytic converters at page 433-434. Operation of separation membranes is known by those skilled in the art and the present invention utilises that existing technology in order to provide the desired oxygen reduced stream 24.

It will be appreciated that various auxiliary conditioning procedures may also be incorporated within the flow path between engine 17 and the converter 25. Thus, the exhaust gas may be cooled and filtered to remove particulate matter potentially detrimental to the membrane 22 and/or the converter 25. Furthermore, the combustion conduction may be controlled to regulate exhaust gas temperature in particular for compatibility within the membrane 22 and/or the converter 25.

Typically, the oxygen concentration in the reduced oxygen stream 24 will be in the range of 2% to 5% by weight. Thus, the converter 25 will have a relatively reducing atmosphere in order to provide oxides of nitrogen conversion whilst the bypass exhaust gas may provide an oxidising atmosphere in the converter 25 subsequent to the conversion of oxides of nitrogen for the elimination of other noxious gases such as carbon monoxide.

CLAIMS

1. An inlet and exhaust arrangement for an internal combustion engine, the arrangement comprising a conduit to present exhaust gas from the engine to an exhaust gas separation membrane whereby the exhaust gas can be divided into a relatively oxygen-enriched stream and a relatively oxygen depleted stream, the oxygen depleted stream being coupled to a converter wherein oxides of nitrogen can be diminished.

2. An arrangement as claimed in claim 1 wherein the conduit includes a bypass whereby the exhaust gas can be directly coupled to the converter.

3. An arrangement as claimed in claim 1 or claim 2 wherein free radicals of nitrogen are injected into the exhaust gas to promote reduction of oxides of nitrogen from the exhaust gas.

4. An arrangement as claimed in claim 3 wherein the free radicals of nitrogen are injected into the exhaust gas upstream of the exhaust gas separation membrane.

5. An arrangement as claimed in claim 3 or claim 4 wherein the nitrogen-free radicals are provided by a plasma generator which utilises a nitrogen-enriched air stream from an air inlet separator membrane used in the air inlet of the engine.

6. An arrangement as claimed in any preceding claim wherein the converter is a three-way catalytic converter.

7. An arrangement as claimed in any preceding claim wherein the relatively oxygen-enriched stream from the exhaust separation membrane is coupled to means for altering the composition of inlet air presented to the engine.

8. An internal combustion engine installation including an inlet and exhaust arrangement in accordance with any preceding claim, wherein the installation includes control means whereby the composition of inlet air presented to the engine can be altered by mixing the relatively oxygen-enriched stream with existing air streams presented to the engine.

9. An intake and exhaust arrangement substantially as hereinbefore described with reference to the accompanying drawing.

10. A combustion engine assembly substantially as hereinbefore described with reference to the accompanying drawing.

The Patent Office
PATENTS • DESIGNS • COPYRIGHT • TRADE MARKS
INVESTOR IN PEOPLE

Application No: GB 9928626.2
Claims searched: 1-10

Examiner: Jeremy Philpott
Date of search: 23 May 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): B1W [WAX]

Int Cl (Ed.7): B01D: 53/22, 53/94; F01N: 3/08, 3/10, 3/24, 3/28, 7/00

Other: On-line: WPI, EPODOC, PAJ

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
A	US 5649517	(University of Chicago) whole document	
A	DE 4331508 C1	(MTU Friedrichshafen GmbH) whole document	
A	DE 4117829 A1	(Frank Luderer) whole document & Figures	
A	JP 06-319949 A	(Toray Industries Inc.) whole document & Figures	
A	JP 06-319948 A	(Toray Industries Inc.) whole document & Figures	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.